ECLSS Ground Coolant Systems

Briefing Topics Overview

- ECLSS Ground Coolant Systems Overview
- ECLSS Shuttle Ground Coolant System Development History.
- Summary of the initial improvement modifications to the S70-0508.
- Features of the new ground coolant system.
- PAD ECLSS Ground Coolant System components.
- Universal Coolant Transporter System.
- Lessons learned.

ECLSS Ground Coolant Systems Overview

When the Space Shuttle Orbiter is powered up the avionics and payloads on board develop heat. This heat must be removed or damage to the equipment occurs. In orbit this cooling is provided by an on-board Refrigerant 21 system chilled by radiators, exposed to space, which are located on the Orbiters payload bay doors. When the vehicle is at the Pad the ECLSS Pad Ground Coolant System (GCS) removes the heat through an onboard vehicle GSE heat exchanger whenever the vehicle needs to be powered up. During Launch the Pad ECLSS Ground Coolant System chills the vehicles on board loop low enough to provide a thermal capacitance for cooling until orbit is achieved.

The GCS also is required for Orbiter power up at the OPF’s, VAB, the SLF/SLS, and was used at Palmdale.

Ground Coolant System History

- 1975 - Rockwell developed the S70-0508 Ground Coolant Unit.
- The S70-0508 consisted of two modules.
- The Circulation Module was developed by Garrett Airesearch.
- The Refrigeration Module was developed by ACL-Filco.

Refrigeration Module
S70-0508-02R

Circulation Module
S70-0508-02C

Ground Coolant System History

- **1976 Thru 1978 - PRC designed Fluid Distribution Systems for all of the Station Sets.**
- **1983 - PRC designed a split flow redundancy panel for the OPF-1 and -2 FDS and a Facility Chilled Water Heat Exchanger for OPF's 1 and 2 and the MLP's, CCBD SSP-05918, ESR 89448, and designed and implemented a vehicle over pressure catch tank system.**

Ground Coolant System History

- **1985 - LSOC designed the Refrigerant Circulation Unit S70-1330 for use at the OPF and VAB. (Works in conjunction with the Chilled Water Heat Exchanger) CCBD E100046-C, ESR 100046.**

Ground Coolant System History

- Late 1985 - LSOC Design to investigate S70-0508 problems and provide final long range solutions per direction from C. Mars.
- Early 1986 - S70-0508 design responsibility was turned over to LSOC from RI.
- Mid 1986 to 1987 - LSOC DE and OPS field tested S70-0508's, recommending interim S70-0508 fixes and the development of a new ground coolant system to be used at all station sets.
- June 1987 - CCBD K13343, issued to create 30% design for replacement of the S70-0508's on the PAD (it being the most critical location) and to create a S70-0508 mod drawing.
- December 1987- LSOC DE released the S70-0508 mod drawing 80K50611.
- January 1988 – S70-0508 mods placed on hold due to lack of funding.
- March 1988 – In house design reached the 30% level, but was placed on hold due to lack of funding.

Ground Coolant System History

- June 1989 – Request made to LSOC activation to utilize the new design as a prototype at OPF-3. (There was not enough S70-0508's to dedicate one to the station set.)
- August to September 1989 – Two S70-0508's modified; remainder put on hold due to lack of funding.
- October 1989 – Implementation of new design for OPF-3 approved by KSC.
- December 1989 – Meeting representing long range S70-0508 replacement presented to level I, CO 452.
- June 1990 – TCTI prepared to modify two additional S70-0508's (Was placed on hold due to lack of funding)
- July 1990 – New OPF-3 design complete.
- October 1990 – FPC established for the new system.
- November 1990 – New system well under construction.

Ground Coolant System History

- December 1990 – Revised the June 1990 TCTI to accomplish modification of three S70-0508's.
- May 1991 – New system power up at KSC.
- September 1991 – New system met OPF-3 ORD. (There was concern by some that the date would not be met.)




Ground Coolant System History

- 1992 – Low point drain design effort, ESR K15280, started for all ECLSS GSE and FDS.
- 1994 – LSOC design performed further testing and evaluation of the OPF-3 GCS.
- 1994 – 1995– LSOC designed the enhanced new ground coolant system for the PAD's.
- 1995 – 1996 – PAD GCS fabricated and installed.
- 1996 – USA designed electrical modifications for the S70-0508's, ESR K15870. This mod almost completely redesigned the circulation unit.
- 2000 – 2001 – USA designed the Universal Coolant Transporter System, ESR K16678. Part of funding came from the ISS after their design failed to meet requirements. (Delivered on time and within budget.)
- August 9, 2005 – UCTS supports the post Columbia, Shuttle landing at DFRC.

Ground Coolant System History

- **UCTS supporting STS-114**

Summary of Initial S70-0508 Modifications

-Refrigeration Module-

- Provided permanent instrumentation for adjustment and trouble shooting.
- Replaced the belt driven condenser coil fan with a two speed direct drive head pressure controlled fan.
- Provided a suction accumulator to prevent liquid R-22 from returning to the compressor.
- Replaced the refrigerant receiver with a receiver equipped with a sight glass and a second sight glass to shine a flashlight.
- Replaced the liquid line sight glass with a see thru type sight glass.
- Replaced the aluminum fin condenser coil with a copper finned condenser coil.
- Properly remounted expansion valve equalizer bulbs.

Summary of Initial S70-0508 Modifications

-Circulation Module-

- **Removed the existing storage cabinet for better component access.**
- **Provide weather sealed blast covers for the instrument panels.**

The basic S70-0508 design (heat load capacity) was still oversized and cannot handle the wide range of heat loads required for launch.

Summary of New Ground Coolant System Features

- Handles a wide range of heat loads.
- Built in redundancy to support launch activity.
- Refrigeration system is based on constants which provides a simple system that is easy to calibrate and trouble shoot.
- System uses proven KSC components.
- System is designed to KSC standards.
- System has open Palletized cabinets providing easy access for maintenance.
- Transducers have built in calibration ports shortening system downtime.
- Inlet piping to units are provided from overhead, eliminating tripping hazards.

Summary of New Ground Coolant System Features

- System is installed in a controlled environment, reducing deterioration and adequate space around the GSE is provided to enhance servicing and operation.
- System has remote fill ports and overhead monorails to aid in servicing.
- Refrigeration system uses water cooled condensers, eliminating environmental fluctuations and mechanism failures associated with air cooled condensers. The UCTS has a direct drive variable speed condenser with ORI and ORD regulators providing hot gas bypass for low ambient days and there is a bypass around the ORI/ORD should it fail.
- All fittings are welded or at the components they are KC/AS style fittings to eliminate leaks.
- System designed with inert materials to make it compatible with multiple fluid medias.

Summary of New Ground Coolant System Features

- All valves and controls are at a single location on each unit. Panel face plates can be removed for easy service access. The manual valves are only used for servicing, not for operation.
- System is of modular construction; components can be replaced with minimal downtime.
- There are no Original Equipment Manufacture (OEM) Components in the units, saving logistics costs.
- The refrigeration units have no complex load control subsystems.
- The refrigeration system is installed in series providing redundant operation which prevents vehicle supply temperature fluctuation and operation intervention during a possible refrigeration unit failure. This feature simplifies launch commit criteria.
- PAD system uses lighter more reliable 7 ton compressors instead of the 20 ton compressors that were in the S70-0508's.

Summary of New Ground Coolant System Features

- System has non-breakable reservoir level indicators.
- System uses analog pressure gages only in areas where pressure in the system can exist when the unit is powered down, otherwise all pressure sensing devices are electronic transducers.
- System has state of the art Phenolic Insulation, with removable sections for component service.
- System has complete support documentation which allows units to be modified for unknown future requirements and enhances operations of the GSE.
- System has Electronic Tech Manuals providing operators real time access to all documentation pertaining to the GSE. (Link to PAD ETM, Link to UCTS ETM).
- System has automatic pump down capability.
- System was considerably less expensive than the S70-0508's.

Summary of New Ground Coolant System Features

-Controls-

- State of the art.
- System is pictorial, providing instant recognition of performance.
- Controls are modular, eliminating downtime.
- Trouble screens instantly identify problems (sources and locations) and provide directions on how to correct them.
- Real time performance calculations can be performed and continuously displayed.
- System has data recall capability providing a signature of the machines performance, history, and reliability.
- Controls are expandable.
- Controls are compact.

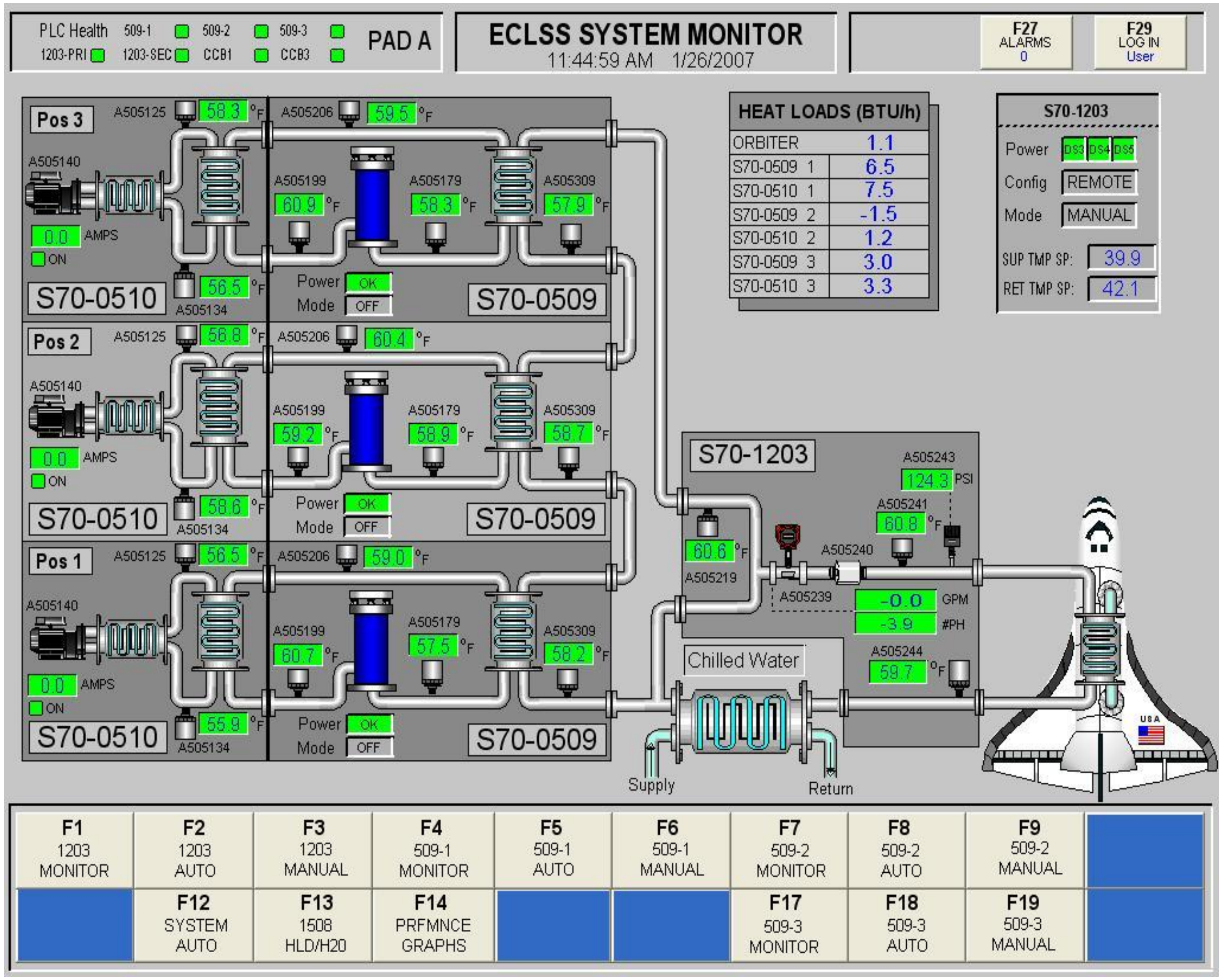
Summary of New Ground Coolant System Features

- Monitor is NEMA IV construction.
- System has LPS redundancy.
- Control functions are more accurate than the S70-0508 equipment.
- The controls do not take away existing capability; rather they enhance it.
- System has full manual capability and full automatic capability.
- System has password level entry preventing inexperienced personnel from damaging the equipment.
- Capability exists to monitor the system remotely and inexpensively.
- Units have independent controls for redundancy.
- Programs are stored in non-volatile memory and are controlled by TDC release.

Summary of New Ground Coolant System Features

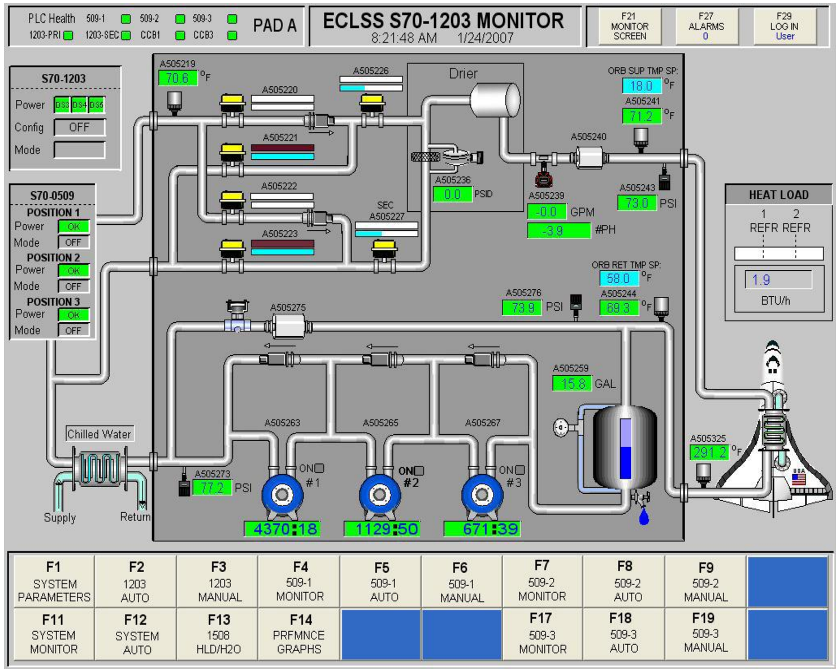
- **System operation is by picture and button and does not require computer knowledge.**
- **Abnormal conditions are clearly displayed and documented.**
- **System history can be stored and recalled on the display to aid in diagnostics.**

Total System Monitoring



The PAD ECLSS System

The ECLSS Ground Coolant System (GCS) is a Space Shuttle Orbiter support piece of Ground Servicing Equipment (GSE) which contains the Program Model Numbers S70-1203-01, S70-0509-01, S70-0510-01 and S70-0898-04. The purpose of the Pad GCS is to provide support services to the Space Shuttle Orbiter during integrated powered up Pad operations and launch at Kennedy Space Center (KSC). The GSE is located in an environmentally maintained enclosure located on the 48 ft elevation at Pad A and the 53 ft elevation at Pad B.



S70-1203-01 ECLSS CIRCULATION/CONTROL MODULE

The S70-1203-01 unit is the primary refrigerant (R124) loop to the Orbiter. It is capable of providing various flows and temperatures of refrigerant to the onboard Orbiter GSE heat exchanger. The module provides the circulation pumps, temperatures, pressures, and flow controls to satisfy Orbiter heat rejection requirements. The unit operates in local and remote modes and provides the necessary instrumentation for monitoring pressures, temperatures, and flows. The unit contains a reservoir with a maximum capacity of 30 gallons of refrigerant.

S70-0509-01 ECLSS CHILLER LOOP MODULE

The S70-0509-01 units (shown on right of the slide) comprise the secondary refrigerant loop that takes the varying heat load of the primary loop (S70-1203-01 on the left of the slide) from the Orbiter and converts it into a constant heat load to the S70-0510-01 refrigeration (R-22) units. These units consists of a pump, heater, and heat exchanger that interfaces with the primary loop. The S70-0509-01 units contains a reservoir with a maximum capacity of 20 gallons (R124) of refrigerant (15 gallons at OPF3).

S70-0510-01 ECLSS REFRIGERATION MODULE

This unit is a simple refrigeration unit that is designed for a constant heat load, and has a 46,000 Btu/hour capability. The unit consists of a compressor, expansion valve, evaporator, suction heat exchanger / accumulator, and instrumentation. The pads use three of these units. The OPF-3 has two.

(Refrigerant used is R-22 and can be updated to R-404 which is environmentally more friendly with minimal changes)

S70-0898-04 Heat Exchanger

This unit is capable of removing 40,000 Btu's heat load and works in conjunction with the S70-1203-01 unit. The heat exchanger uses chilled water to remove heat from the S70-1203 R-124 refrigerant that passes through it.

S70-0898-04

S70-1508-00 Chilled Water/Industrial Water Interface Station

The interface station provides the system operator with chilled water flow and temperature information. It provides the capability to switch to potable water in the event of a chilled water system failure. The station is operated by a command and execute (two steps) command process that controls nine valves to configure either chilled or potable water.

S70-1508-00

Universal Coolant Transporter System

- **The UCTS presented a unique design challenge since we desired to essentially have the PAD system capability and redundancy on the limited space of a transporter. This involved modifying the secondary / primary loops pump arrangements and modifying the compressor sizing.**

Speed Channel: American Trucker – NASA Video Season 1, Episode 12 (Original Air Date: 06/09/2011)

Lessons Learned

No significant support problems were encountered during the operation of Ground Cooling System GSE for Shuttle support from November 13, 1999 to present. A Problem Report count total of less than one hundred for twelve years of service support for the Shuttle program attests to the thorough thought process that went into the core requirements needed during the design stage for this GSE.

From 1975 to 1986 the S70-0508's had 527 PR's, over five (5) times more than the new GCS for an equivalent time period!

Lessons Learned

-Future system enhancements-

- **An important lesson learned from the Universal Coolant Transporter System (UCTS) is that CRES-reinforced braided Teflon lined flex hoses are permeable to atmospheric moisture, where there is stagnant media and the vapor pressure of allowable moisture for the internal media is less than the vapor pressure of moisture in ambient air. This was significantly mitigated (but not solved) on the UCTS Boom flex hoses using an inline dryer, vapor barrier tape, and modified processes (e.g. boom isolation to reduce amount of moisture transferred from the stagnant boom subsystem to the UCT module). Future design would be to use convoluted metal bellows flex hoses to eliminate the Teflon lined flex hose moisture permeability issue.**

- **Importance of having a fixed recovery system at the vehicle interface, for operational set up time reduction.**

- **The MAWP should be changed from 250 psig to 500 psig (this was designed for in the UCTS).**

- **Use R-134a instead of R-124 for the fluid transfer media (primary loop / secondary loop) and use R-404 instead of R-22 for the refrigeration cycle (R-404 is used in the UCTS).**

Lessons Learned

- **Gaps in post-Shuttle *(Pad B)* Pressure Vessel processes found and fixed.**

  Gap inspired an integrated, visual approach to create required work instructions.

  NTR Case # KSC-13619, TRL = 2

Lessons Learned

A graphical user interface is used to integrate: